Multi-Pipe String Electromagnetic Detection Tool and Its Applications

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Abstract: The MID-K, a new kind of multi-pipe string detection tool is introduced. This tool provides a means of evaluating the condition of in-place pipe string, such as tubing and casing. It is capable of discriminating the defects of the inside and outside, and estimating the thickness of tubing and casing. It is accomplished by means of a low frequency eddy current to detect flaws on the inner surface and a magnetic flux leakage to inspect the full thickness. The measurement principle, the technology and applications are presented in this paper.

Keywords: Electromagnetic detection; tubing and casing; corrosion monitor; well integrity and safety

1 Introduction

Well casing and tubing integrity is a very important component in the safe operations of a well in the oil & gas production. To maintain safe operating conditions through out the life of a well, operators must periodically determine the integrity of the down hole well tubular.

Historically, inspection of production tubing has been limited to mechanical calipers. In 1960, the first casing inspection tool (CIT) was introduced to the oil industry, and since that time a number of corrosion monitor logs have been recorded in various areas. Some paper reported the results obtained with the casing inspection tool [1]. But the reported tool only used in single casing well corrosion monitor. The electronic casing caliper tool (ECCT) was a new tool that measured the internal diameter of pipe in a well and recorded the curve at the surface. Run with the casing inspection tool, the caliper log determined whether metal loss or casing damage has occurred internally or externally [2]. These kinds of corrosion monitoring techniques were summarized by Fincher before 1972 [3]. Up to 1974, Schlumberger Company carried out casing inspection log PAL and ETT. PAL provided the ability to discriminate between defected on the inner and outer walls of a single pipe string of casing. ETT provided the wall-thickness information and located severe corrosion or defected in the outer casing of a double pipes string [3]. The method of phase drift in ETT was first use to measure wall-thickness in double pipes string. In 1988, Schlumberger offered Pipeline Corrosion Tool and Video Camera (PCTVC), a means to detect corrosion in lines with diameters from 3 1/2 to 12 inches [4]. After 1990, the corrosion monitoring was become more important in the oil field and many new kinds tools were carried out. Such as MFL, UST, MTT, PIT, DHTV etc [5-9]. In the future, computer processing of digital caliper and thickness data supports 3D visualization results [10]. The engineer can quickly and accurately understand the details of localized tubing or casing damage.

2 Electromagnetic Detection Tool MID-K

The MID-K tool consists of two parts. One is upper and lower centralizer, another is electronic module. The electronic module includes four sensors: a vertical exciter coil, two horizontal receiver coils, and a temperature sensor. The exciter coil and receiver coil used to inspect corrosion and damage of pipe string. The temperature sensor used to measure environment temperature which can indicate fluid flow from where.

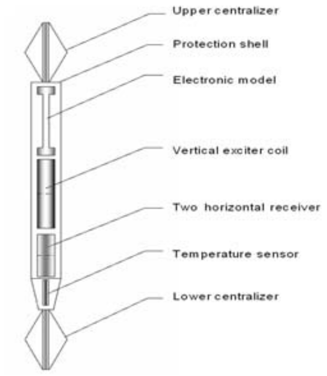

Fig. 1 sketch of MID-K tool

3 Measurement Principle

The MID-K inspection tool uses a method of measuring the effect of eddy currents on a magnetic field. The signal of induced voltage is measured. It is

$$\varepsilon = S \cdot dB / dt$$

Where: ε-induced voltage, S-cross section of receiver coil, B-magnetic power, t-time. B related with thickness of pipe wall, ε-measured signal which related with attenuation of magnetic field. The thickness of pipe wall will be estimated from ε and t.

Fig. 2 is a block diagram of the measurement principle. The exciter coil is fed from an AC source at the surface, and the resulting magnetic field sets up eddy currents in the tubing and casing walls.

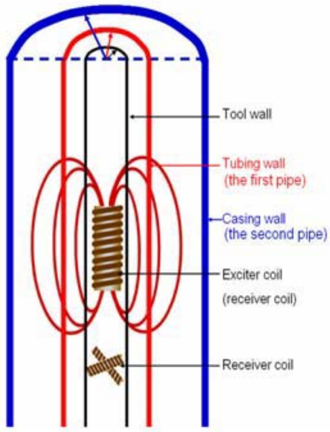

Fig. 2 Measurement principle

These eddy currents cause the magnetic field to be attenuated, and the resulting magnetic field is detected by the receiver coil. The amplitude and delay of signal in receiver coil related to four factors: pipe wall thickness, frequency, magnetic permeability and conductance of the metal. The basic induced voltage equation which follows shows that the induced voltage is directly proportional to pipe wall thickness, magnetic permeability, pipe diameter and temperature. If a single pipe string, the signal of receiver coil is a function of five factors:

$$\varepsilon = f_{(T,\mu,\sigma,D,te)}$$

Where: T-pipe wall thickness, μ-magnetic permeability, σ-pipe conductance, D-pipe diameter, t-temperature.

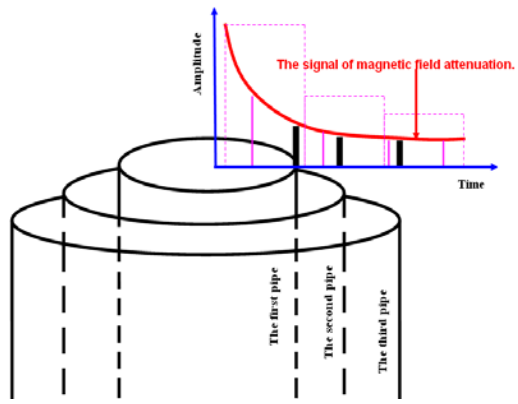

Fig.3 relationship between measured signal of magnetic field attenuation, pipe diameter, wall thickness and time.

If two pipes strings, the *T, μ, σ,D, te* will be double, the signal of receiver coil will be influenced by ten factors. Although the factors of magnetic permeability and conductance of the metal pipe are always unknown for any tubing and casing. The magnetic field attenuation and amplitude of the induced signal will be change if a pipe is damage or corrosion. From this change we can know the construction, damage, corrosion information of tubing and casing by using a metal pipe thickness scale. Fig. 3 shows the relationship between measured signal of magnetic field attenuation, pipe diameter, wall thickness and time. The quantitative thickness of the first and second pipe can be estimated from attenuation signal.

4 Applications

The following section contains some examples of MID-K response to typical defects in pipe string. From fig.4 to fig.10, the GK is the curve of γ ray. The I5-I54 is the signal of magnetic attenuation in vertical receiver. The 1P2-1P4 is the first horizontal receiver signal. The 2P2-2P4 is the second horizontal receiver signal. The T1 is the estimate thickness of the first pipe string. The T2 is the estimate thickness of the second pipe string. Fig.4 and fig.5 have been made up to illustrate the nature of the response to each type of defect. Fig.6 to fig.10 was some typical examples from oil field.

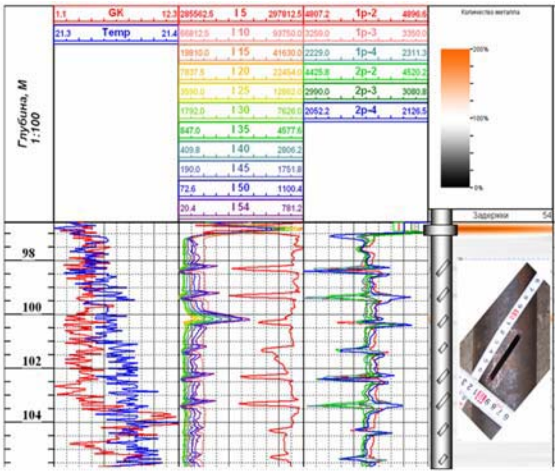

Fig. 4 response of MID-K in incline split model pipe. The split is wide 3-5mm, and long 30-60mm.

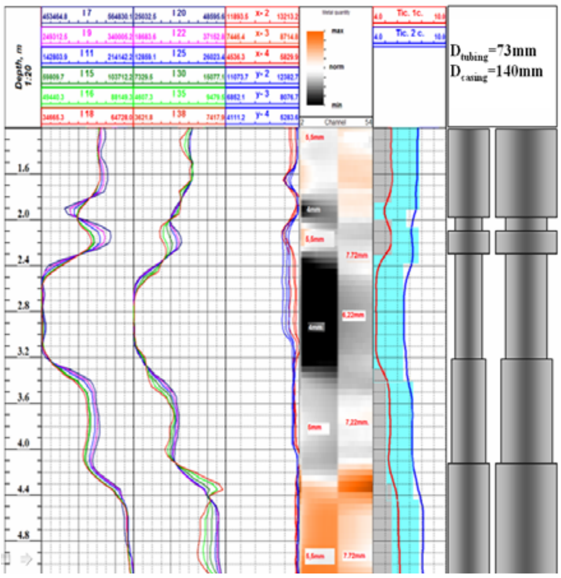

Fig. 5 response of MID-K in double model pipe string. The first pipe is D=73mm, and the second one is D=140mm. There are five kinds of wall thickness on the pipe string. The measured response agrees with pipe model obviously. The result of quantitative interpretation is given at right track. The red curve in right is D73, and blue curve is D140.

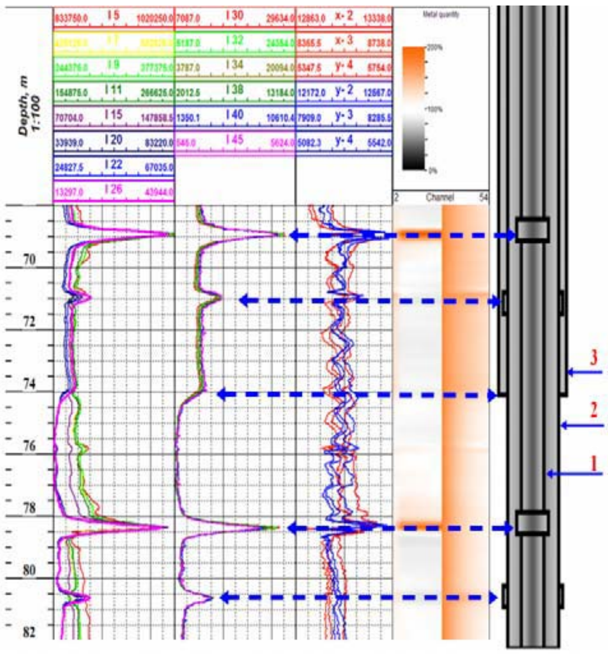

Fig. 6 response of three pipes string in oil production well A8. The first pipe string is tubing D73. The response amplitude of tubing is higher. The second pipe string is casing D140.The third pipe string is surface casing D178. Its diameter is larger, and the response amplitude is lower.

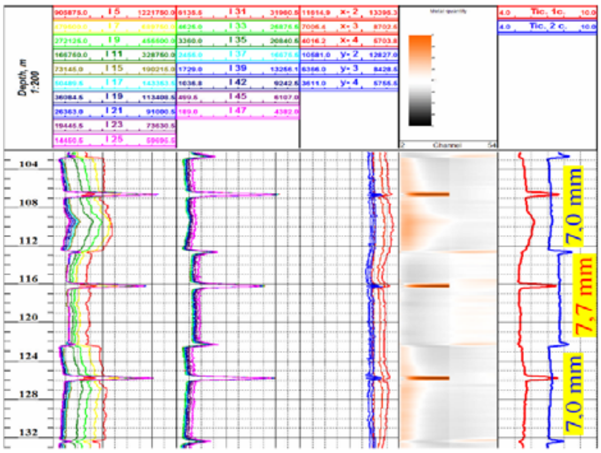

Fig. 7 result of MID-K shows that the thickness of one of casing wall have 7.7mm from 112.5 to 122.5 m in oil production well A8. Its wall thickness is different from others.

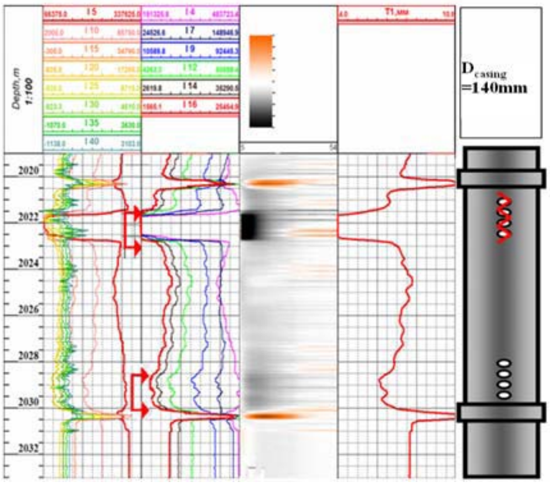

Fig. 8 result of MID-K shows that the casing was broken from 2021.5m-2023m in oil production well A8.

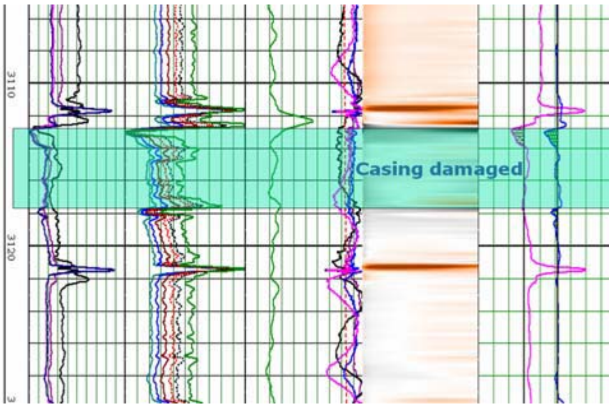

Fig. 9a result of MID-K shows that the casing have been damaged from 3112.5-3112.7m in gas production well A14.

The detail information was shown in fig.9b.

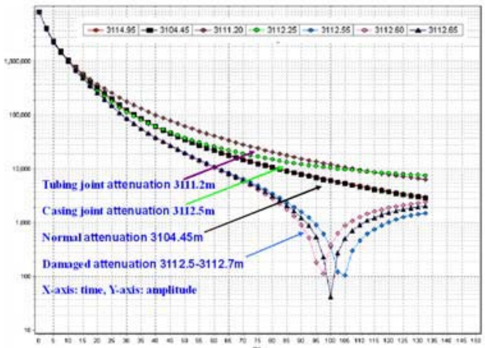

Fig.9b result of MID-K shows that magnetic attenuation signal in different depth in gas production well A14. The magnetic attenuation signal has a big difference between normal pipe (3104.45m) and damaged pipe (3112.5-3112.7m).

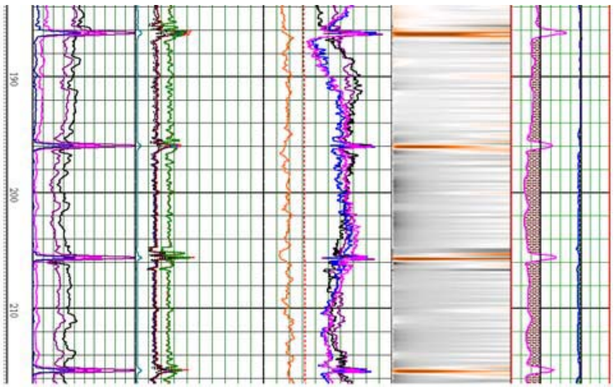

Fig. 10a result of MID-K shows that tubing are server corrosion from 186.1m-215.5m in gas production well A14. Fig.10b is a photo of tubing that pulled out from this well.

Fig. 10b This photo is a profile of tubing comes from gas well A14. The outside surface of tubing is not corrosion. But the photo of inside profile shows us the inside surface is server corrosion. They worked in gas well about 10 years from 200m to well head.

5 Conclusion

The MID-K provides a means of evaluating the condition of tubing and casing. It is capable of discriminating the defects of the inside and outside, and estimating the wall thickness of double pipes string. The applications in the oilfield show that MID-K is a good choice to detect and analysis multi-pipe string in the oil field.

Reference

[1] Edwards, J.M., Stroud, S.G., McCullough Tool Field Results of the Electromagnetic Casing Inspection Log, Journal of Petroleum Technology, April, P377-382, Authors, 1964.

[2] EDWARDS, J.M., STROUD, S.G., McCULLOUGH TOOL Co.， New Electronic Casing Caliper Log Introduced For Corrosion Detection, Journal of Petroleum Technology, Issue August P933-938, 1966.

[3] Fincher, D.R., Nestle, A.C., Fincher Engineering Co.A Review of Corrosion Monitoring Techniques, SPE Symposium on Handling of Oilfield Water, 4-5 December, Los Angeles, California, 1972.

[4] Edwards, R.C., Schlumberger Well Services, Pipeline Corrosion Logging: A New Application of Wireline Surveys, SPE Gas Technology Symposium, 13-15 June, Dallas, Texas, 1988.

[5] Sperling, E. J., Sharp, C.Q., MacLean, A.R., Amoco Corporation; Spencer, D.W., Microline Corporation, Downhole Corrosion Inspection of 2 7/8 and 3 1/2 Inch Production Tubing Using Magnetic Flux Leakage,SPE Annual Technical Conference and Exhibition, 22-25 October, Dallas, Texas,1995.

[6] G. Frisch, B. Mandal, Halliburton Energy Services, Advanced Ultrasonic Scanning Tool and Evaluation Methods Improve and Standardize Casing Inspection, SPE Annual Technical Conference and Exhibition, 30 September-3 October, New Orleans, Louisiana,2001.

[7] A.P.Potapov and L.E.Kneller. Numerical Solution to a forward and an inverse problem in tem wall-thickness measurements of well casing. Russian Geology and Geophysics, Vol 42, No.8, PP1213-1218, 2001.

[8] D.C. Vogtsberger, Baker Atlas, and B. Girrell, J. Miller, and D. Spencer, Microline Technology Corp.Development of High-Resolution Axial Flux Leakage Casing-Inspection Tools, SPE Eastern Regional Meeting, 14-16 September, Morgantown, West Virginia. 2005.

[9] Manish Kumar Sinha, SPE, Indian School of Mines, Pipeline Corrosion: Its Remote Detection and Corrosion Management, SPE Eastern Regional Meeting, 11-13 October, Canton, Ohio, USA,2006.

[10] J.Y. Julian, D.A. Cismoski, and R.O. Younger, BP Inc., J.P. Burton and M.W. Use of 3D Visualization Software for Multi-finger Caliper Analysis at Prudhoe Bay, Alaska, SPE/ICoTA Coiled Tubing and Well Intervention Conference and Exhibition, 20-21 March, The Woodlands, Texas, U.S.A.2007.

Author Biography

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